

MEG recording for spatial S-R compatibility task under adaptation to right-left reversed vision

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1. Introduction

Human recognizes objective world properly, even though a reversed image was mirrored on the retina. This had started the study of reversed vision, particularly in cognitive psychology, and the adaptation to reversed vision has been studied for many years. A subject can hardly walk just after reversed vision. As the adaptation progresses, he becomes to move at will. However, it is still unclear the mechanism of adaptation, especially how brain activities readjust to reversal of the retinal image. Few studies about reversed vision have reported several changes of the brain activity [1][2].

Recently, the non-invasive measuring techniques of brain function enable to observe brain activity under adaptation to reversed vision in a noninvasive manner. We focused on the activity in the primary visual and motor cortex and performed MEG recording, which has high sensitivity for cortical activities and good in resolution of time-space.

We took notice of the relationship between visual and motor information in right-left reversed vision. Simon task [3] was used as the spatial Stimulus-Response compatibility task for MEG recording. The Simon task is a choice reaction time task, composed of the stimulus and response attributes (e.g. location, color, etc.), match (compatible task) or not (incompatible task). It is known that, in the Simon task, reaction in the compatible task is faster and more accurate than in the incompatible task. This is called the Simon effect.

We performed two experiments in winter in 1998 and in fall in 1999. Because we considered the affection of the first experiment, the second experiment was performed after enough time.

2. Methods

2.1. Subject and period

In both experiments, a same male subject who was 22 years old in 1998 and normal for health

participated. He wore right-left reversing goggles, constructed from a pair of Dove prisms, continuously for 17 days in the 1998 experiment and for 16 days in the 1999 experiment. In the period of reversed vision (RV), he didn't get any non-reversed visual information. The period of normal vision (NV) was for two days after reversed visual period in the 1998 experiment, and for four days before and after respectively in the 1999 experiment. MEG recording was performed everyday for reversed visual period and normal visual period in all experiments.

2.2. MEG recording

In the 1998 experiment, we performed VEF experiment and Simon task experiment using the visual stimulus. VEF experiment was performed in the every morning and evening. Simon task experiment was done in the every evening. In the 1999 experiment, Simon task experiments of the visual and auditory stimulus were done respectively on alternate days in turn.

In the 1998 experiment, visual stimuli were produced with a liquid-crystal projector that projected an image on a screen. In VEF experiment, the subject only looked at a fixation point and a square stimulus appeared on the right or left side of the fixation point without apparent motion. Each stimulus was 150 trials respectively, i.e. the total of stimulus were 300 trials. The stimulus was shown during 300 ms. And ISI was 1 ± 0.5 s at random. In Simon task experiment, a triangular stimulus turned to right or left appeared on the right or left side the fixation point. Therefore, stimuli were four types; 1) the triangle turned to right on the right side (compatible), 2) left on the right (incompatible), 3), right on the left (incompatible), and 4) left on the left (compatible). The subject was instructed to move his index finger according to the direction of triangular stimulus appeared through the reversing goggles. Reactions were gotten by recording

electromyogram (EMG) of moved index finger. And during MEG recording, his hands were set out of his sight. Each stimulus was 100 trials respectively, i.e. the total of stimulus was 400 trials in one recording. The stimulus was shown during 300ms. And ISI was 6 ± 1 s at random.

In the 1999 experiment, the visual stimuli were produced with LED and the auditory stimuli of 1000 Hz pure tone were produced with a multifunction generator. Because stimuli were only two types (right or left), the compatible task and the incompatible task were performed separately in each experience. And the subject's hands were placed in his sight differently from the 1998 experiment. In the visual Simon task experiment, the LED lighted on the right or left side of the fixation point. In the compatible task, the subject moved his index finger visible in the same side of LED, and the opposite finger in the incompatible task. Each stimulus was 100 trials respectively, i.e. the total of stimulus were 200 trials in the compatible task and the incompatible task. LED lighted during 300ms. And ISI was 5 ± 1 s at random. In the auditory Simon task experiment, the subject heard auditory stimulus through a right or left earphone and reacted in the same side of sound in the compatible task, and the opposite finger in the incompatible task. The stimulus duration was 100ms. Other conditions were same as in the visual Simon experiment.

The brain magnetic fields were recorded using a 64-channel whole-cortex MEG system (CTF Systems Inc., Canada).

2.3. Data analysis

Daily MEG data, eliminated trials containing noisy waveform or responded incorrectly, were averaged. In the VEF experiment, daily averaged MEG data were grand averaged over 3 or 4 days. Data of Simon task experiments were averaged by synchronizing with stimulus onset (stimulus synchronous) and reaction time (reaction synchronous). The brain activities were examined with an equivalent current dipole (ECD) model. Since the iso-contour maps of MEG were complicated, signal subspace projection [4] was used to calculate the active strength of estimated dipoles. We examined the active strength of estimated motor dipoles for the daily averaged data.

3. Results

3.1. Behavioral observation

Since the subject experienced the reversed vision for the first time in the 1998 experiment, he was sick for the first few days because of the swinging of visual

scene. But, the adaptation advanced in such a condition and uncomfortable feeling was almost cleared up after one week. Finally, he adapted so much as to walk freely and to act voluntarily and actively. In the 1999 experiment, the adaptation proceeded more quickly by the experience in 1998. After three days, he became similar to the final state in 1998. Finally, he got to catch a thrown ball. Therefore, he adapted to the reversed vision all right.

3.2. VEF experiment

All data were well reproducible. In the late latency, the activity amplitude showed a tendency to increase day after day. But, no change related to the adaptation was observed. Fig. 1 displays the MEG waveforms and iso-field maps for the stimulus in the right visual field.

3.3. Simon task experiment

In the 5th day in the 1998 experiment and the 15th day in the 1999 experiment, MEG could not be recorded because of apparatus trouble.

Fig. 2 illustrates the reaction time of each Simon task. In the 1998 Simon experiment and the 1999 visual Simon task experiment, the Simon effect appeared in the reaction time (RT). But in the 1999 auditory Simon task experiment, the Simon task was reversed against expectation, i.e. the task performance was better in the incompatible task than in the compatible task, during RV. Incidentally in the 1998 Simon experiment, RTs in RV and NV were interchanged each other, because same stimulus was seen differently in RV and NV.

MEG changed depending on RT in all experiments. It was more remarkable for the reaction synchronous than the stimulus synchronous. These changes

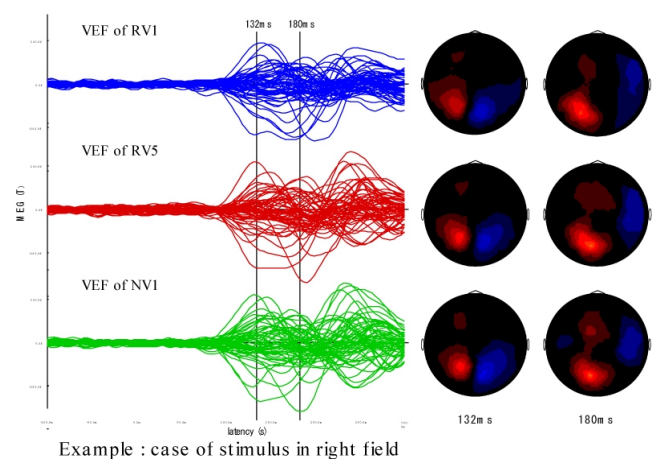


Figure 1. MEG waveforms and iso-field maps in the VEF experiment. RV1 was averaging of 1st ~ 4th day. RV5 was 14th ~ 16th day. NV1 was 1st ~ 3rd day after RV.

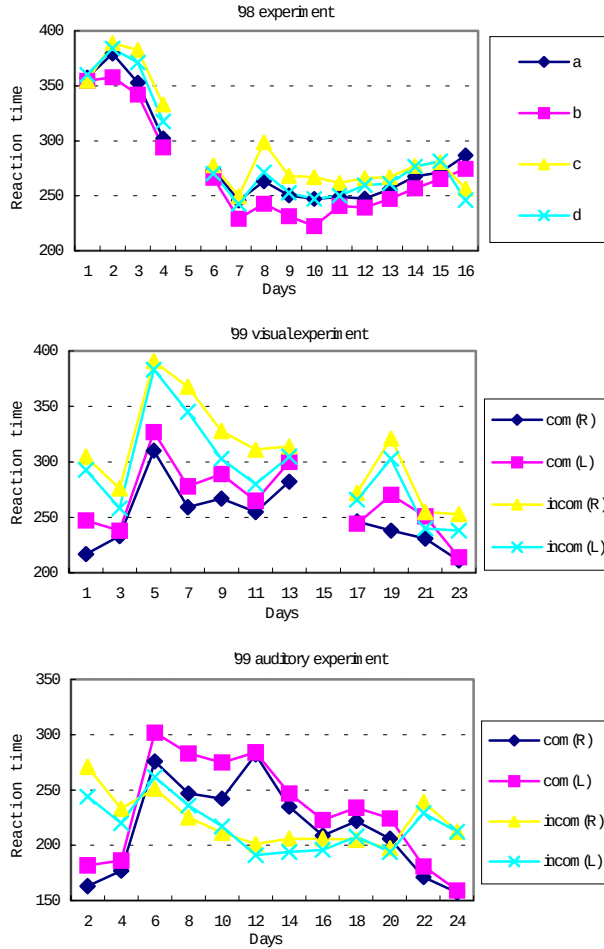


Figure 2. Reaction time for Simon task. In 1998, *a* is stimulus turned to right on the left side (R@L) in RV and right on the left (L@R) in NV. *b* is R@R in RV and L@L in NV. *c* is L@R in RV and R@L in NV. *d* is L@L in RV and R@R in NV.

seemed to have no connection with adaptation. Fig. 3 displays the MEG waveforms and iso-field maps averaged by synchronizing with reaction (the right hand compatible task, the visual and auditory Simon task in 1999).

3.4. Activity strength of estimated dipoles

The activity of visual dipole in the VEF experiment didn't change. As for the motor dipole, position and direction was estimated from the data in the 1998 Simon task experiment and fixed to calculate the activity strength in all data. The activity of motor dipole was relatively larger in NV than in RV and increasing during the RV period. Fig. 4 illustrates the time courses of left motor dipole's activity averaged by synchronizing with the reaction (the right hand compatible task, the visual and auditory Simon task in 1999).

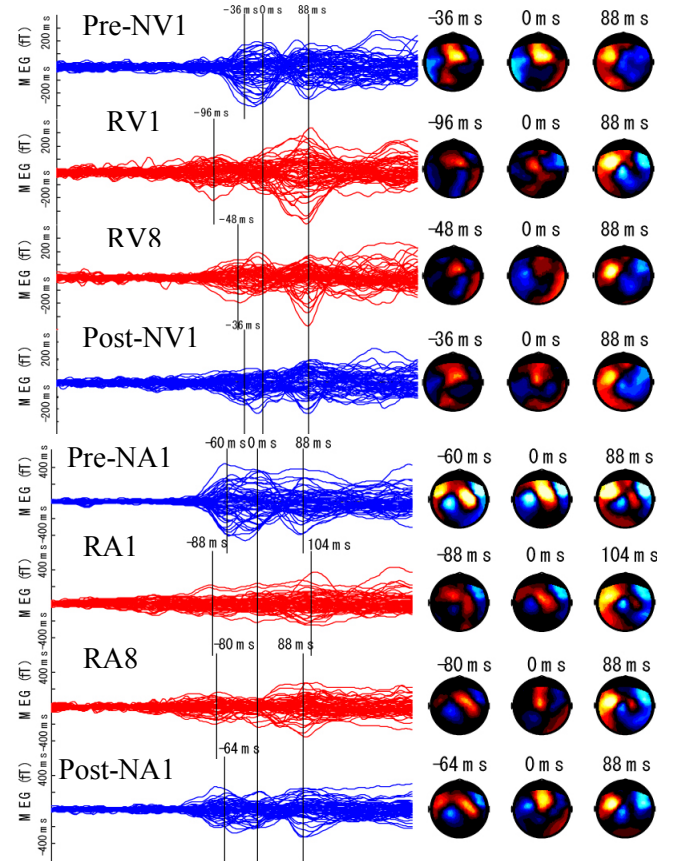


Figure 3. MEG waveforms and maps averaged by synchronizing with RT (right hand movement in the compatible task, in the visual (top four) and auditory (bottom four) Simon task in 1999). Pre-NV1 was 1st day in NV. RV1 was 1st day in RV. RV8 was 15th day in RV. Post-NV1 was 1st day in NV after RV. Pre-NA1 was 2nd day in NV. RA1 was 2nd day in RV. RA8 was 16th day in RV. Post-NA1 was 2nd day in NV after RV.

4 Discussion

We started this study to confirm the research that had reported the change of early VEP in the right-left reversed vision [1]. In the VEF experiment, though VEF showed a small tendency to increase day after day in the late latency, the visual activity in the early latency didn't change. Therefore, we concluded that VEF did not change in connection with adaptation to the right-left reversed vision.

As for the results of the Simon task, the Simon effect appeared in the 1998 and 1999 visual Simon task experiment, and reversed in the 1999 auditory Simon task experiment. In the 1998 Simon task experiment, because the subject's hands were placed out of view during the experiment, reversed vision had few influence on this task. In the 1999 auditory Simon task experiment, it is very interesting that though response needs no visual information in the task, Simon effect was reversed because of reversed

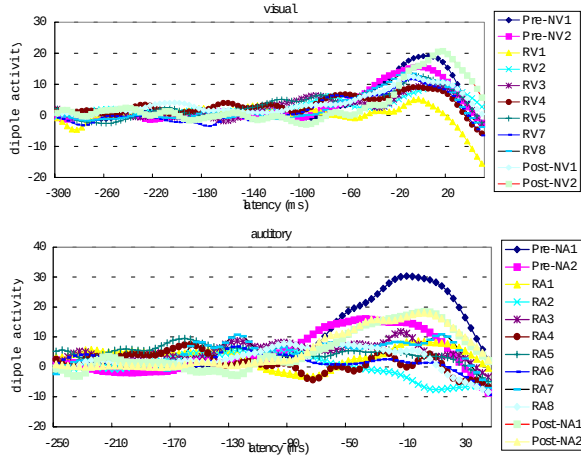


Figure 4. Left motor dipole activities averaged by synchronizing with RT (right hand movement in the compatible task, the visual (upper) and auditory Simon task (lower) in 1999.

vision. It might be caused by feedback from reversed vision. When an auditory stimulus was gotten from a right ear in the right-left reversed vision, the subject felt more compatibility in moving his left hand seen in his right sight (incompatible) than his right hand seen in his left sight (compatible). And in the 1999 visual compatible task, the stimulus and response were matched in the sight. However in the hemisphere, not matched (e.g. real right hand movement for left visual stimulus). Therefore, it was suggested that visual sense was more dominant than other senses.

The motor activity for the Simon task seemed to be related to the reaction time. And so we examined correlation between the motor dipole activity and RT. Table 1 shows coefficients of correlation between the maximum amplitude of the motor dipole activity and RT in each experiment. And Fig. 5 illustrates the distribution chart with the maximum amplitude of the motor dipole activity and RT. There was a tendency to negative correlation particularly in the compatible task. Therefore, it was inferred that dipole activity was larger in good performance of the task, because preparative activity in the primary motor cortex was more synchronized with movement execution.

Table 1: Coefficients of correlation between the maximum amplitude of the motor dipole and RT

experiment	total	L-com	L-incom	R-com	R-incom
'98 visual	-0.158	0.217	0.219	-0.425	-0.391
'99 visual	-0.445	-0.799	-0.314	-0.835	0.253
'99 auditory	-0.564	-0.872	0.091	-0.738	0.134

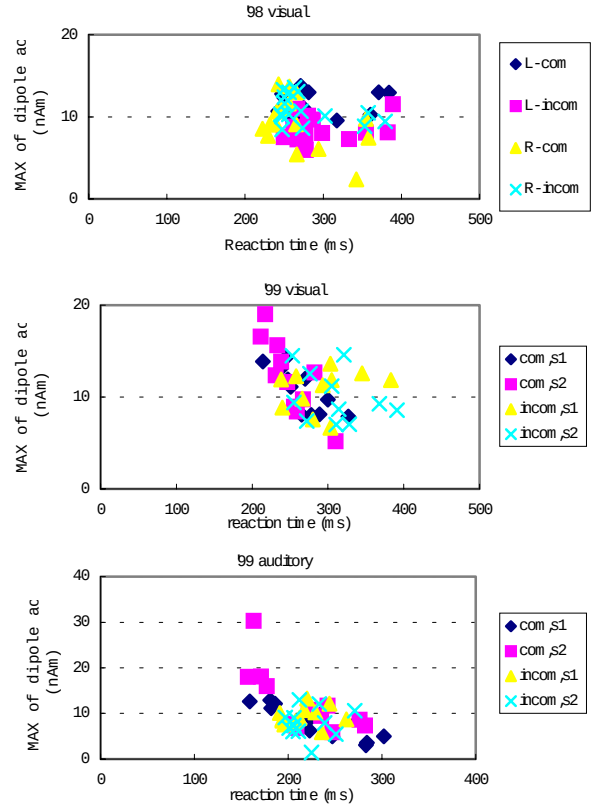


Figure 5. Distribution map with the maximum amplitude of the motor dipole and RT in the 1998 Simon task experiment (upper), in the 1999 visual experiment (middle), in the 1999 auditory experiment (lower).

Acknowledgements

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